REMARKS

Applicants are amending their claims in order to further clarify the definition of various aspects of the present invention. Specifically, Applicants are amending each of claims 1, 2, 21 and 25, all of the independent claims in the application, to recite that the multi-mode optical waveguide has a geometrical central axis, and wherein light of a basic mode propagating in the at least one incident light waveguide (A) enters on the geometrical central axis of the multi-mode optical waveguide. See, for example, Section [0004] on pages 4 and 5 of Applicants' specification. Claims 1 and 2 have been further amended to further clarify that the "other end" recited is the other end "of the multi-mode optical waveguide".

Applicants respectfully submit that all of the claims presented for consideration by the Examiner patentably distinguish over the teachings of the references applied by the Examiner in rejecting claims in the Office Action mailed November 24, 2008, that is, the teachings of the U.S. patents to Johannessen, et al., No. 6,970,625, and to Ido, No. 6,236,784, under the provisions of 35 USC 102 and 35 USC 103.

It is respectfully submitted that the teaching of these references as applied by the Examiner would have neither disclosed nor would have suggested such a light branching optical waveguide, or such optical device having such light branching optical waveguide, as in the present claims, including, inter alia, wherein the waveguide includes at least one incident light waveguide (A) optically connected to one end of a multi-mode optical waveguide, with light of a basic mode propagating in the at least one incident light waveguide (A) entering on the geometrical central axis of the multi-mode optical waveguide, and output light waveguides (B), larger in number than the number of incident light waveguide(s) (A), optically connected to the

other end of the multi-mode optical waveguide, wherein an intensity distribution of light entering from at least one optical waveguide (a), of the at least one incident light waveguide (A), into the multi-mode optical waveguide at a connecting surface of the at least one incident light waveguide (A) and the multi-mode optical waveguide, is asymmetric with respect to a geometrical central axis of the waveguide (a), the at least one optical waveguide (a) having a curved structure, with light entering from the at least one optical waveguide (a) into the multi-mode optical waveguide, and with light having a wavelength entering at least two of the output light waveguides (B) from the multi-mode optical waveguide, so as to branch the light from the multi-mode optical waveguide having the same wavelength into each of the at least two of the output light waveguides (B); and (i) an extended line of the geometrical central axis of the at least one optical waveguide (a) does not coincide with a geometrical central axis of the multi-mode optical waveguide (see claims 1 and 3), and/or (ii) a core shape of the multi-mode optical waveguide is asymmetric with respect to a geometrical central axis of the multi-mode optical waveguide (see claim 2).

Furthermore, it is respectfully submitted that the teachings of the references as applied by the Examiner would have neither disclosed nor would have suggested such a method of manufacturing a light branching optical waveguide as in the present claims, the light branching optical waveguide having structure including the waveguides (A), (B) and (a), and the multi-mode optical waveguide, with light of a basic mode propagating in the at least one incident light waveguide (A) entering on the geometrical central axis of the multi-mode optical waveguide, the at least one optical waveguide (a) having a curved structure, with light entering from the at least one optical waveguide (a) into the multi-mode optical waveguide, and with light having a wavelength entering at least two of the output light waveguides (B) from the

multi-mode optical waveguide, so as to branch the light from the multi-mode optical waveguide having the same wavelength into each of the at least two of the output light waveguides (B); the method including positioning the at least one optical waveguide (a), which has the curved structure, such that an extended line of the geometrical central axis of the at least one optical waveguide (a) does not coincide with a geometrical central axis of the multi-mode optical waveguide (see claim 21), or wherein the method includes forming a core shape of the multi-mode optical waveguide to be asymmetric with respect to a geometrical central axis of the multi-mode optical waveguide (see claim 25).

As will be discussed in more detail infra, it is respectfully submitted that the teachings of the applied references, including Johannessen, et al., in particular Fig. 5 thereof, would have taught away from the presently claimed structure and method wherein, inter alia, light of a basic mode propagating in the at least one incident light waveguide (A) enters on the central axis of the multi-mode optical waveguide. It is respectfully submitted that the position of entry of light of the basic mode propagating in the at least one incident light waveguide (A) with respect to the central axis of the multi-mode optical waveguide, according to the present invention, is different from the position of the incident light waveguide of the 2x2 coupler as in Fig. 5 of Johannessen, et al.

Moreover, as also discussed further infra, it is respectfully submitted that the principles of the light branching optical waveguide according to the present invention, and that of the 2x2 coupler described in Johannessen, et al., are completely different from each other. In connection with the 2x2 coupler, the input power will be coupled into an output waveguide 206, 208 (see Fig. 5 of Johannessen, et al.), with a desired output power splitting ratio being achieved by setting the coupling length L, as

discussed in column 7, lines 28-44, of Johannessen, et al. In contrast, where the length of the core of the multi-mode optical waveguide according to the present invention is changed, the number of peaks of the propagating light would be changed.

In connection with the principles under which the 2x2 coupler of, e.g., Fig. 5 of Johannessen, et al., operates, and in connection with operation of the presently claimed light branching optical waveguide, attention is respectfully directed to the enclosed article of Soldano, et al., "Optical Multi-Mode Interference Devices Based on Self-Imaging: Principles and Applications", in Journal of Lightwave Technology, Vol. 13, No. 4 (April 1995), pages 615-627. Note, in particular, Table 1 on page 620 of this publication. It is respectfully submitted that the light branching optical waveguide of the present invention corresponds to the symmetric type disclosed in the right-hand column of this Table 1 on page 620 of the enclosed publication, with the input location being y=0. The first N-fold image distance is $3(L\pi)/4N$. When the number of outputs (N) is 2, the first N-fold image distance $3(L\pi)/8$ is very short. On the other hand, the 2x2 coupler of Johannessen, et al. corresponds to the general type disclosed in the left column ("General") of Table 1. When the number of outputs (N) is 2, the first N-fold image distance $3(L\pi)/2$ is much longer than that of the light branching optical waveguide of the present invention. Accordingly, a symmetry type light branching optical waveguide is usually used for getting a branching ratio of 1:1 in the branching of light, different from the structure of Johannessen, et al.

Furthermore, it is respectfully submitted that the teachings of the applied references would have neither disclosed nor would have suggested such light branching optical waveguide as in the present claims, having features as discussed previously in connection with claims 1-3, and, additionally, having features as in the

dependent claims, dependent ultimately on claims 1 and 2, including, inter alia (but not limited to), wherein an optical central axis having a peak intensity in the intensity distribution of light entering into the multi-mode optical waveguide from the at least one optical waveguide (a) substantially coincides with the geometrical central axis of the multi-mode optical waveguide (see claims 4 and 12); and/or wherein the core shape of the multi-mode optical waveguide has a notch at at least one of its side edges (see claims 5 and 13), particularly wherein such notch is obtained by a technique as in claims 6 and 14, especially with a shape of the notch as in claims 6 and 14; and/or wherein the at least one incident light waveguide (A) includes one incident light waveguide and the output light waveguides (B) include at least two output light waveguides, with a branching ratio between quantities of light branched into the at least two respective output light waveguides (B) being substantially equal (see claims 7 and 15); and/or wherein at least one of the at least one incident light waveguide (A) and the output light waveguides (B) include a single-mode optical waveguide (note claims 8 and 16); and/or materials of the core or clad of the multi-mode optical waveguide, as set forth in claims 9, 10 and 17; and/or offset distance between the extended line of the geometrical central axis of the at least one optical waveguide (a) and the geometrical central axis of the multi-mode optical waveguide, as in claims 19 and 20.

In addition, it is respectfully submitted that the teachings of the applied references would have neither disclosed nor would have suggested such a method as discussed previously in connection with claims 21 and 25, and including additional features as in claims dependent on claims 21 and 25, including (but not limited to) wherein the at least one incident light waveguide (A) is one incident light waveguide (A), the at least one optical waveguide (a) is one optical waveguide (a),

and the output light waveguides (B) are at least two in number (see claims 24 and 28).

Moreover, it is respectfully submitted that the teachings of these applied references would have neither disclosed nor would have suggested such light branching optical waveguide, or such method, as in the present claims, having features as discussed previously in connection with claims 1, 2, 21 and 25, and, moreover, wherein the at least one optical waveguide (a) is directly optically connected to the multi-mode optical waveguide (see claims 29-32); and/or wherein the light entering the multi-mode optical waveguide from the at least one optical waveguide (a) has said wavelength (see claims 33-36); and/or wherein the wavelength is a single wavelength (see claims 37-40).

The present invention is directed to a light branching optical waveguide and optical device using the same, as well as a method of manufacturing such light branching optical waveguide. Such waveguide and device are used in optical transmission systems, and there has been a growing demand for such systems with the recent widespread use of personal computers and the internet.

An optical branching circuit and an optical multiplexing circuit serving as basic elements are indispensable to an integrated optical circuit, and an optical waveguide branched to provide a Y shape has been conventionally known. A multi-mode interference type Y branch optical waveguide has been known, and various kinds of such multi-mode interference type Y branch optical waveguides have been proposed, as discussed in the paragraph bridging pages 4 and 5 of Applicants' specification.

However, various problems arise in connection with such multi-mode waveguides. For example, equal branching ratio of light is achieved only in the case

where the mode of light propagating in the incident waveguide is a basic mode alone, where the basic mode is symmetric with respect to the central axis of the incident waveguide, where the central axis of the incident waveguide and that of the multi-mode waveguide coincide with each other, and where the multi-mode waveguide is of a shape symmetric with respect to its central axis. In the case where the intensity distribution of light propagating in an optical waveguide on an incident side is asymmetric with respect to the geometrical central axis of the optical waveguide, there arises a problem that the branching ratio of light cannot be equal. Moreover, it is noted that when the incident light waveguide has a curvature, the basic mode is generally asymmetric.

Furthermore, in a multi-mode type light branching optical waveguide, the position at which light of a basic mode and light of a higher-order mode interfere with each other varies depending on a wavelength. Thus, there arises the additional problem that each of a loss of light intensity and a branching ratio is dependent on the wavelength. Accordingly, as the design of the multi-mode type light branching optical waveguide must be changed in accordance with the wavelength of the light, there arises a still further problem of, e.g., reduction of efficiency of production of the waveguide.

Against this background, and as described in the second full paragraph on page 7, and in the paragraph bridging pages 7 and 8, of Applicants' specification, the present inventors have found that a branch loss and a variation in branching ratio can be reduced, in structure wherein light of a basic mode propagates in the at least one incident light waveguide (A) on the central axis of the multi-mode optical waveguide, by shifting position of the geometrical central axis of the optical waveguide (a) such that it does not coincide with the geometrical central axis of the

multi-mode optical waveguide, and/or by making the core shape of the multi-mode optical waveguide asymmetric with respect to the geometrical central axis of the multi-mode optical waveguide, even when the intensity distribution of light propagating in an optical waveguide on an incident side is asymmetric with respect to the geometrical central axis of the optical waveguide.

To emphasize, having investigated specific problems of branch loss and a variation in branching ratio, arising in connection with light branching optical waveguides using multi-mode optical waveguides and incident light waveguides wherein at least one of the incident light waveguides has a curved shape, and wherein light of a basic mode propagates in the at least one incident waveguide on the central axis of the multi-mode optical waveguide, Applicants have found structure which avoids these problems, achieving a light branching optical waveguide having a reduced branch loss and a reduced variation in branching ratio; and, additionally, provide structure wherein not only are such branch loss and variation in branching ratio reduced, but the light branching optical waveguide has a small wavelength dependency.

Thus, Applicants have found that, with light branching optical waveguide structure including at least one incident light waveguide that is curved and a multi-mode optical waveguide, as in the present claims, a branch loss and a variation in branching ratio can be reduced by an offset between the geometrical central axis of the incident light waveguide and the geometrical central axis of the multi-mode optical wavelength. Note the last full paragraph on page 16 of Applicants' specification.

Applicants have also found, as a further feature of the present invention, that by forming the core shape of the multi-mode optical waveguide to be asymmetric

with respect to the geometrical central axis of the multi-mode optical waveguide, light propagating in the multi-mode optical waveguide is provided with an intensity distribution having two nearly equal peaks, so that the branching of light at a branching ratio of 1:1 can be achieved.

In addition, as described in the paragraph bridging pages 19 and 20 of Applicants' specification, a low-loss, multi-mode, light branching optical waveguide having a reduced branch loss, a reduced variation in branching ratio and small wavelength dependence is achieved, where the extended line of the geometrical central axis of an incident light waveguide does not coincide with the geometrical central axis of the multi-mode optical waveguide, and the core shape of the multi-mode optical waveguide is asymmetric with respect to the geometrical central axis of the multi-mode optical waveguide. Note, in particular, the paragraph bridging pages 20 and 21 of Applicants' specification.

Thus, note that the light branching optical waveguide of the present invention has a function of achieving the branching of light to a branching ratio of 1:1 (equal) in the case that the light exhibits asymmetry in the incident waveguide. To accomplish this, it is important to change asymmetric light of the optical waveguide (a) to a symmetric light. <u>A problem to be solved by the present invention is changing an asymmetric light caused by optical waveguide (a), having the curved structure, to symmetric light</u>. This problem is solved by the present invention; i.e., by providing the branching ratio between the quantities of light branched into the two output light waveguides to be substantially equal, this means that the intensity distribution of light has been changed to symmetrical distribution.

It must be emphasized that according to the present invention, a low-loss light branching optical waveguide having a reduced branch loss and reduced variation in

branching ratio is provided, even though the intensity distribution of light propagating in an optical waveguide on an incident side is asymmetric with respect to the geometrical central axis of the optical waveguide, e.g., due to the use of the curved incident optical waveguide (a).

Johannessen, et al. discloses optical splitters and couplers, having an input signal on section 12 (see Fig. 1) coupled into a linear taper section 14, which expands the fully excited fundamental mode for coupling into the waveguides 28, 30. The structure further includes a straight section 22, this straight section 22 having a lateral width equal to that of the leading edge 20 of the linear taper section 14, and allows the signal at the leading edge 20 to couple into the output waveguides 28 and 30 with less loss than other structures formed from blunt sections. Note, in particular, the paragraph bridging columns 3 and 4, as well as the first full paragraph in column 4, of Johannessen, et al. As applied by the Examiner, note Fig. 5 and descriptions in connection therewith in column 7, lines 19-44 of this patent. The structure disclosed in Fig. 5 includes Y-branches 202 and 204 having straight sections between a gap and the branching waveguides, which is a 2x2 coupler.

As can be particularly seen in Fig. 5 of Johannessen, et al., it is respectfully submitted that Johannessen, et al. would have neither taught nor would have suggested, and in fact would have taught away from, such light branching optical waveguide, device or method as in the present claims, having, inter alia, light of a basic mode propagating in the incident light waveguide entering on the central axis of the multi-mode optical waveguide, as part of the overall structure. Again, Applicants respectfully emphasize that in Fig. 5 of Johannessen, et al., a 2x2 coupler is disclosed, completely different from the light branching optical waveguide of the

present claims, including, inter alia, positioning of the entry of the light of the basic mode propagating in the incident light waveguide as in the present claims.

In this regard, it is respectfully submitted that in Johannessen, et al., there is no problem that the branching ratio of light is unequal, due to asymmetry of the intensity distribution of incident light for the 2x2 coupler; in contrast, such inequality of the branching ratio of light is a problem to be solved by the present invention in which the connecting position of the incident light waveguide is on the central axis of the multi-mode optical waveguide. Again, this problem of inequality of branching ratio of light is solved by the present invention, having features as set forth, for example, in the last three lines of claim 1, and last two lines of claim 2.

It is respectfully submitted that the additional teachings of Ido would not have rectified the deficiencies of Johannessen, et al., such that the presently claimed invention as a whole would have been obvious to one of ordinary skill in the art.

Ido discloses an optical waveguide and a lightwave circuit, with the optical waveguide being an asymmetric Y branch optical waveguide as described most generally in the last full paragraph in column 2 of this patent. See also the paragraph bridging columns 2 and 3, as well as the first full paragraph in column 3 of this patent. Note also column 9, lines 34-50.

Even assuming, arguendo, that the teachings of Johannessen, et al. and of Ido were properly combinable, such combined teachings would have neither disclosed nor would have suggested the structure and method of the present claims, including wherein light of a basic mode propagating in the incident light waveguide (A) enters on the central axis of the multi-mode optical waveguide, problems arising in connection therewith, and the structure provided in the present claims overcoming such problems.

In view of the foregoing comments and amendments, reconsideration and allowance of all claims presently pending in the application are respectfully requested.

To the extent necessary, Applicants hereby petition for an extension of time under 37 CFR 1.136. Kindly charge any shortage of fees due in connection with the filing of this paper, including any extension of time fees, to the Deposit Account of Antonelli, Terry, Stout & Kraus, LLP, Account No. 01-2135 (case 396.46073X00), and please credit any overpayments to such Deposit Account.

Respectfully submitted,

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